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ABSTRACT

This document presents the 1970 W. O. Atwater Memorial Lecture, delivered at the Third International Congress of Food Science and Technology, Washington, D.C., August, 1970. Elaborating on life a few centuries hence, using reasonably realistic prospects based on understanding already available, Handler contends that the dreams of a peaceful, future society are indeed feasible. His principal thesis is that, even now, science has provided the basis of understanding necessary to fashion many elements of this society and that it will be fulfilled if mankind can survive the crises of this century. Reviewing the nature of some of the crises and the potential contributions of biological sciences to their solutions, he examines the problems of population, food supply, environmental quality, resource utilization, and world peace. Summary statements indicate that biological and physical research can permit us to refashion ourselves and our world, and that if the dream fails, it will be because of the limitations of man the social creature, not the elements of science. (BL)

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Can Man Shape His Future?

The 1970 W. O. Atwater Memorial Lecture

AGRICULTURAL RESEARCH SERVICE • U.S. DEPARTMENT OF AGRICULTURE

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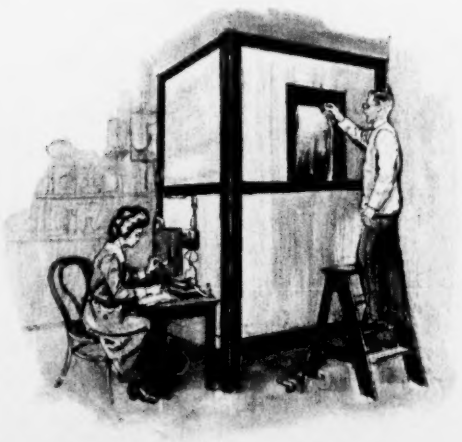

THE W. O. Atwater Memorial Lecture was established in 1967 by the Agricultural Research Service of the U.S. Department of Agriculture to honor the memory of a gifted scientist . . . and to recognize accomplishment in a field or discipline that relates to the problems of nutrition and feeding the hungry world.

Dr. Wilbur O. Atwater (1844–1907) was a man of many talents. He was a scientist, teacher, lecturer, research administrator, and writer . . . motivated always by a deep concern for improving the welfare of people through better nutrition.

Dr. Atwater established the science of modern human nutrition in the United States, and directed the first nationwide program of nutrition research, centered in the Department of Agriculture. He was the first director of America's first agricultural experiment station at Wesleyan University, Middletown, Connecticut, and the first director of the Federal Office of Experiment Stations.

Dr. Atwater's most basic contributions to nutrition stemmed from his studies on food metabolism. He perfected, among other things, the first satisfactory calorimeter for measuring the expenditure of human energy.

His early warnings about the dangers of overeating and lack of exercise, and the need for protein for mental and physical health are being corroborated by scientists everywhere.

Dr. Atwater wrote extensively to popularize scientific information and to arouse public interest in nutrition.

The 1970 W. O. Atwater Memorial Lecture

presented in cooperation with
The Third International Congress
of Food Science and Technology
Washington, D.C.
August 11, 1970

Can Man Shape His Future?

by Dr. Philip Handler, President, National Academy of Sciences, Washington, D.C.

IT is a high privilege to give *The 1970 W.O.Atwater Lecture,* as it is to appear before so many distinguished visitors from outside our borders. On behalf of the National Academy of Sciences, I bid you all welcome and extend our hope that you find these days rewarding and enjoyable.

Authors of science fiction have provided numerous versions of life a few centuries hence. What are the reasonably realistic prospects, based on understanding already in hand? The pace of scientific and technological achievement has so dramatically changed man's capabilities in the last few decades and brought so many surprises that any projected vision will necessarily be less dramatic than the future reality.

Surely the world's population will have stabilized, although at what level is uncertain. The racial balance will

undoubtedly be rather different from that at present. Although Caucasians made up 20 percent of the world's population in the 17th century, they now represent about 40 percent of all people. But the trend has reversed, and the more heavily pigmented populations are increasing disproportionately. These gene pools will undoubtedly undergo more mixing than at present, but with what results for the future of the species one cannot say.

The bulk of humanity will be gathered in megalopolises, dwelling in huge buildings surrounded by park lands, perhaps covered by domes within which the atmosphere is maintained rather constant. Outside them, the fields are verdant, lakes and streams clear.

Power consumption per capita will be vastly greater even than in the United States today. The price per kilowatt will have been greatly reduced by the introduction of thermonuclear plants capable of 1 million megawatts output or more, thanks to utilization of magnetohydrodynamics and of superconductive materials both for the generation and transmission of power. Water will be abundant, thanks to efficient desalination made possible by the cheap power; thermal pollution will have been replaced by a variety of uses of the heated effluents of these power plants, such as desalination, domestic heating, and year-round agriculture.

Each individual will have a private, pocket, two-way television instrument and immediate, personal access to a computer serving as his news source, privately programmed educational medium, his memory, and personal communicator with the world at large, with his bank, broker, government agents, shopping services, etc.

Less than 5 percent of the working population will be

engaged in primary agriculture, with no more than another 20 percent engaged in other primary productive activities such as food processing, mineral extraction, construction, or manufacturing. The bulk of the labor force, then, will engage in activities currently classified as services rather than production of goods. The principal pursuits of mankind will be cultural, recreational, or devoted to the expansion of knowledge and understanding.

Most of the diseases that have been man's most ancient enemies will be matters of historic interest only, and each individual may look forward to about fourscore years of vigorous, healthy, pain-free life before succumbing to the ravages of old age.

If, indeed, humanity survives to see such a world, necessarily by then national aspirations will have been sublimated to some form of world order; a single worldwide police force will maintain law and order, and the arsenal of nuclear weapons, ballistic missiles, and diverse countervailing measures will long since have been dismantled.

Embroider that image with such detail as you will, such as the probable changes in the materials used for a wide variety of purposes, in the nature of distribution procedures, in educational mechanisms, in management of the environment, in conservation of the natural resources of the planet, in modes of short- and long-haul transportation, in the uses of outer space and of the oceans, in the social structure of the family—if families there be, and in the use of mood-altering drugs. For all that vision of a brave new world, the most dramatic developments simply cannot be anticipated.

Most of us hold such a dream in common, differing only in detail and the color of our imaginations. The most

important thing one can say about that dream is that it may well be feasible. My principal thesis is that, even now, science has provided the basis in understanding necessary to fashion many elements of the dream; and it will be fulfilled if mankind can survive the crises of this century. Allow me to review the nature of some of these crises and the potential contributions of biological science to their solutions.

Foremost among them is the need to secure a stable world peace. And I find it a matter of deep regret that so few of the technical community, so few students, are addressing themselves to this problem, that the disturbed generation is not deeply disturbed by the world's ever-growing nuclear arsenal.

But my subject is really the second problem—which can be teased apart into the fragments identified as population, food supply, environmental quality, and resource utilization—but which is really one major problem.

CONCERN for population is scarcely novel. In his "Politics," Aristotle warned that, ". . . neglect of an effective birth-control policy is a never-failing source of poverty which in turn is the parent of revolution and crime." Hence, he advocated that parents with too many children practice abortion. But he went unheeded through the following centuries as the Romans—and their successors to this time—encouraged large families to man their far-flung armies, the Judeo-Christian ethic considered children as gifts of God, and St. Augustine averred that the purpose of marriage is procreation, a view unmodified even by the Reformation. Yet before St. Augustine, Tertullian had

stated that, "Scourges, pestilence, famine, earthquakes, and wars are to be regarded as blessings to crowded nations, since they serve to prune away the luxuriant growth of the human race."

From time to time, other advocates of population control appeared, most notably Malthus, who stated that populations would always rise to the limits made possible by food production so that, necessarily, there must always be hunger and poverty. Ironically, Malthus rested his case on the history of the United States in the 18th century. Unfortunately, his teaching was rejected by both the Christian ethic and by Marxism, which taught that overpopulation is a capitalist notion invented to justify the poverty of working-class peoples, rectifiable by enhanced production and improved distribution rather than by birth control.

Opponents of measures to effect population control argue that, given the time and effort required to increase all forms of agricultural productivity sufficiently, earth can sustain a population vastly larger than that at present in nutritional abundance. Undoubtedly this is the case. We do not now face the global crisis Malthus predicted, nor shall we, although we most certainly will in some *specific* locales. Since about 1950, worldwide agricultural productivity has grown by about 3 percent annually, while population increase has averaged just under 2 percent. If worldwide per capita food consumption had remained constant at 1955 levels, despite the population increase, by 1975 there would have been a world surplus of 40 million tons of wheat and 75 million tons of rice. This will not occur because of both rising per capita food consumption and the controlled agricultural productivity practiced in varying degree and kind in the United States, Australia,

New Zealand, Canada, and the Argentine.

Meanwhile, however, some developing nations, caught up in the worldwide revolution of rising expectations, find themselves short of both food and capital for development. The specter of famine may have been averted in the Philippines, Pakistan, Mexico, and parts of India as a consequence of the much-publicized "Green Revolution" and, be it admitted, several consecutive years of favorable monsoons. But that specter remains in other areas of the world, and it is difficult to see how some will avoid wholesale famine in the coming two decades without large-scale help from the major agricultural producers. Thereafter, known technology could so expand food production as to avoid world food problems almost indefinitely. But, meanwhile, malnutrition is desperately serious in some tropical and semitropical countries. Around the globe it remains a leading cause of death and disability.

The combination of new strains and application of fertilizer that has so remarkably increased crop yields in Europe, Japan, and the United States has now been demonstrated to work in several developing nations. For $35 billion per year—or $10 per capita worldwide—out of a Gross World Product of $3,000 billion, global food production could rise by the equivalent of the basic productivity of 1.7 billion acres of average tillable land, thus providing a 50-percent increase in available food per capita worldwide.

Moreover, it has been calculated that if all the land now in tillage were managed as in Holland, the world could support 60 billion people on a typical Dutch diet; if managed as in Japan, it could support 90 billion people on a typical Japanese diet. And all of this is apart from the

realizable expectations we all hold for the next agricultural or, more accurately, food revolution based on improved control of agriculture, on culture of food yeast or other microorganisms, and on synthetic nutrients. Approximately 1 acre is required to feed one man by efficient current agriculture, yet a 1-square-yard tank growing algae can produce all of his caloric, protein, and vitamin needs. If that product were used to feed chickens, hogs, or cattle, 10 square yards would suffice for a man, woman, or child. All of which is to state that measures to upgrade agricultural practice in the developing nations could forestall a Malthusian crisis for at least a half century, even at current rates of population growth, and perhaps indefinitely.

But with what consequences?

Surely the fact that it might be possible to feed such huge populations does not justify a policy of uncontrolled population growth, although the most frequently employed older argument for population control rested on the Malthusian approach. But it need not, and probably will not, be the food supply that limits our future populations or the quality of our civilization. The most cogent argument for population control is that if, as now estimated, world population will approximately double by the turn of the century, and if it were possible to raise the standard of living for all of that population so that it would become comparable to that of the average American citizen of today, the drain on the world supply of natural resources would then be 70 times that in 1950, and the drain on the biosphere would be about 6 to 8 times that of today. Our planet, our environment, could not conceivably tolerate a continuing insult of that magnitude.

Whatever the biologically maximum possible population

might be, it is patently very much larger than at present, very much larger than that which most of us might consider to be optimal. Even a 1-percent growth rate, with a doubling time of 70 years, will soon be unacceptable, else all of mankind must, undoubtedly, accept living standards inferior to those some of us already know.

Patently, even our present numbers suffice to populate the planet with the diversified human talent required to contribute to progress on all human fronts—science, the arts, industry, government, etc. Meanwhile, many of the most tragic ills of human existence find their origin in population growth. Hunger, pollution, crime, despoliation of the natural beauty of the planet, extermination of countless species of plants and animals, overlarge, dirty, overcrowded cities with their paradoxical loneliness, continual erosion of limited natural resources, and the seething unrest which engenders the political instability which leads to international conflict and wars—all derive from the unbridled growth of human populations. If humanity is ever to realize its potential, if life in that future world is to be worth living, population growth must be checked.

Granted that several Western nations have stabilized their populations by a variety of means, nothing could so much advance this cause as a totally reliable, reversible, safe, very cheap contraceptive device or procedure, preferably such that error or carelessness would result in failure of conception, rather than the reverse. No such procedure is presently available, and this major challenge to students of reproductive physiology is now being explored vigorously.

While we await that means, available procedures are quite acceptable first approximations. Both the plastic IUD

and the steroid pill illustrate the character of many major problems that confront us. For both, there appears reason to believe that an occasional—although unfortunately unpredictable—user may be injured, even killed thereby. But the overall death rate is considerably less than that from pregnancy itself, and both their users and society benefit from the reduced birth rate. Hence, one should encourage use of these procedures, while recognizing their undesirable attributes. It is this kind of "trade-off" of risk vs. benefit that characterizes all decisions concerned with the quality of life, necessary to achievement of the greater good for the greater number.

BRIGHT as the very long term prospects could be, the immediate future is difficult indeed. If we fail, truly larger populations could well result, irreversibly, in the end of civilization as we have known it, much less as it might be—a return to barbarism and dark ages, well put by an ancient poet:

"A wise man may grasp how ghastly it may be
When all this world's wealth standeth waste
Even as now, in many places over the earth,
Walls stand wind beaten,
Heavy with hoar frost; ruined habitations . . .
The maker of men has so marred this dwelling
That human laughter is not heard
And idle stand these old giant works."

The problems differ sharply in the developed and developing nations. Although population growth is faster in the latter, the immediate penalty for such growth is far

greater in the former. As compared to a native of the Amazon jungles, an Indian village, or a Nigerian small town, or to the Egyptian fellahin, we make enormously greater impact on the environment and on our resources. Each American is entitled, by birth as it were, to a school desk, a dormitory bed, a hospital bed, perhaps 400 square feet of a personal dwelling space, 16 feet of steel on the highway and all the gasoline he can burn, as well as 30 grams of animal protein per day. To add to such a consuming population is horrendous to contemplate. The difficulty in merely sustaining the life of a Brazilian native may loom even larger—but it has little impact on the reserves of coal, oil, iron ore, copper ore, or phosphate rock and contributes little to the despoliation of the environment.

Current projections suggest that by the year 2000, as compared with 1950, oil consumption in the United States will rise by 500 percent, automobile production by 700 percent, residential construction 1000 percent, chemicals and chemical products 1200 percent, air passenger miles 2600 percent, highway construction 2000 percent, electric power consumption by 1800 percent, and disposable per capita income, in constant dollars, by 250 percent! If unchecked, we could undoubtedly create the industrial plant and technical capability to realize those projections. But there are grave doubts that our resources or environment could tolerate the result; "America the Beautiful" would have been desecrated beyond the limits of tolerance of her custodians.

Hence, the growing sense of urgency that, in advanced nations, population growth be minimized, that economic growth be slowed while we develop a coherent quantitative

model of our national life, establish what order of resource utilization and recycling, of land use, etc. is compatible with a harmonious steady state with our resources and environment, develop a commensurate national population policy, and effect social action programs that can, in time, assure that all Americans enjoy the full advantages of citizenship. We have made a small start in this direction, but only that. Meanwhile, well-intentioned legislation concerned only with automotive emissions or nonreusable beer containers, important as it may be, is much like prescribing aspirin for a brain tumor.

The magnitude of future contributions from the "have" to the "have not" nations is of great moment. For the latter, enhanced agricultural productivity is the chief hope for the accumulation of the capital required to pay the costs of entry into our technological civilization. And yet, it is in just those countries where the problems of food shortages may become acute. If they are to escape that crisis, they can do so only by the importation of capital from the developed world, capital to provide seed, fertilizer, power equipment, irrigation, etc. Without external help, the race between food supply and population will be marginal, and it is difficult to see any hope of capital accumulation for societal development. The burden then lies with the developed world. It is their decisions that will determine the future of the vast masses of humanity in the developing "third world."

As that development succeeds, the per capita drain on resources must rise, as will the insult to the environment, defeating the very purposes of development—enrichment of the quality of life. If, however unworthy it may seem to some of you, the goal is to have all of humanity share the

current American standard of living, the planet itself simply cannot tolerate successful development. Hence, the acute need for worldwide population control—now. Large-scale assistance to developing nations will have, at first, the effect of a brake on economic growth in the advanced nations, itself a desirable goal. Other, perhaps even more painful, consequences must also be recognized: as development succeeds, the smaller the gap in education and general life style between the now developed and less developed worlds becomes, the greater will be the resentment of the remaining differential, as we have seen happen within our own borders.

In this sense, such assistance could be planting the seeds of later conflict, a dilemma whose resolution is not presently apparent, yet must not be a deterrent on purely humanitarian grounds. In any case, for the moment, that isn't the problem. In general, the gap between us is widening rather than closing.

However successful that outcome, *all* nations must concern themselves with preserving and protecting their environments and resources. So much has been said about this problem in recent times that further elaboration would be unwelcome. Nevertheless, it is imperative that we recognize that we know little and badly require scientific understanding of the nature and magnitude of our actual environmental difficulties.

The current wave of public concern has been aroused in large measure by scientists who have occasionally exaggerated the all-too-genuine deterioration of the environment or have overenthusiastically made demands which, unnecessarily, exceed realistically realizable—or even desirable—expectations. While we must be grateful to them,

unhappily also through their efforts, science is thought in the minds of some to have contributed to the deterioration of the quality of life; science is equated with technology and both are judged to be immoral.

The manner of directing attention to these problems has turned much of the general public, many decision makers, and a yet larger fraction of our youth, against science. I regard them in much the same light as I do those who proclaimed an extraordinary widespread malnutrition in the United States at the recent White House Conference on Nutrition, but produced no quantitative data to substantiate their allegations. The nations of the world may yet pay a dreadful price for the public behavior of scientists who depart from established fact to indulge themselves in hyperbole.

Alarmed voices advocate retreat from our technological civilization as if life had been better in some bygone age when our ancestors lived closer to nature than do we, desiring a return to good old days that never were. For my part, I much prefer that we attempt to manage our technological civilization yet more successfully, remedying the errors of the past, building the glorious world that only science-based technology can make possible.

It is the profundity and widespread concern of the moment that is so surprising. Perhaps this reflects our great frustration in finding successful approaches to yet more vexing social and international political questions, and it is simply a great relief to speak to concerns that most can share, particularly now that one cannot even be in favor of motherhood. Should that be the case, it would be well to take maximal advantage of the opportunity. It will surely pass as public concern and interest turn elsewhere, as the

public and its political representatives begin to take environmental deterioration as much for granted as they now do the presence of an arsenal of nuclear weapons.

I cannot, however, share the facile criticism of industry and Government, damned by the more violent, anarchical enemies of the Establishment as showing a history of unconscionable misdeeds. The course of history could scarcely have been otherwise. How unlikely is a scenario in which concern for the consequences to the quality of the environment would have begun concomitant with the origins of the industrial revolution, when the esthetic and hygienic state of every major city was then far less acceptable than is that of any city of the moment.

It is in the nature of homeostatic systems to overshoot, to register the resultant aberration, and make appropriate corrections. Man and his societies are no exception. All of our history is one of action and reaction. Rather than condemn the past, be grateful that the environmental movement is now sufficiently strong to provide opportunity to rectify our errors and chart a new course for the future while there is time. And there is yet time.

In the advanced nations, life for most persons was never so long, so rich in experience, so comfortable as it is today. In some senses, the environment was never cleaner. It is not evident that that is equally true in many developing nations—the curse of population growth. But even there, in most instances, population growth is not so much the consequence of increased fertility as it is of the sharp decline in the childhood death rate resulting from introduction of relatively primitive sanitary procedures. Indeed, as such families come to believe that their young, their living insurance policies, will survive, contraception or abortion

will surely gain far greater acceptance.

Air pollution in this and other countries is certainly serious. It has engendered large-scale unpleasantness but not yet serious damage to man or his fellow creatures. Technology already in being or readily fashioned can rectify the more serious aspects of degradation of air quality, and I consider this a relatively temporary, albeit important, problem. Despite some relatively recent statements, there is absolutely no likelihood of a significant reduction in atmospheric oxygen. Even if all of the known fossil fuel reserves of the world were to be burned tomorrow, this could engender a reduction of only a few percent; our oxygen supply is vouchsafed for the indefinite future. However, the consequences of buildup of atmospheric carbon dioxide are quite uncertain; indeed, one does not know whether, on balance, the results might even be beneficial.

There are certainly streams and lakes that have been woefully injured, sewers for a melange of all of the chemical outpourings of our civilization. Yet, happily, this is reversible for the most part. The history of Lake Washington, outside Seattle, is a case in point. Once well on the way to the current status of Lake Erie, concerted action has so purified that lake that it now has difficulty in sustaining its salmon population! We already possess knowledge of diverse measures that, collectively, would permit restoration of most such bodies of water. In some instances, they would be rendered cleaner—if I may be permitted the use of that word—than ever they were in nature.

But all such activities have a price, a price which, in the end, must be passed on to the consumer, with a resultant decreased rate of production of wealth as conventionally

measured. Since virtually everyone is agreed that this is well worth the cost, that such activities are not only acceptable but imperative, they constitute little problem for the construction of appropriate public policy.

Those of us in the Western world find it somewhat ironic that the planned societies of Eastern Europe have followed the same disastrous course and now must confront the same problems. What is even sadder to contemplate, however, is the prospect that, in their eagerness to attain the life style of advanced nations, developing nations may similarly injure their own environments and deplete their natural resources even more rapidly than did we. In those nations, the price for environmental protection is a significant limitation on the pace of development, which is already marginal at best. Public officials who seek to implement programs of environmental protection in those nations will have to look to generations yet to come for approbation. In all likelihood, their contemporaries will be impatient and indignant.

Man's place on earth is historically unique. For the first time, decisions knowingly made by one species determine the number and variety of all other species. The heritage of all of the physical and biological evolution of the planet is ours alone; no other species can consider or affect its own destiny. And that places upon us an awesome responsibility. To be sure, natural cataclysms and the workings of evolution have already resulted in the extinction of 95 percent of all species that have ever appeared on earth. But we can determine history hereafter. In managing the earth's limited resources, it will be tragic if we neglect this responsibility and permit passing cupidity irreversibly to destroy the remarkable diversity of life.

Man long since exterminated the flightless moa, the passenger pigeon, and we know not how many others. The international irresponsibility of the whaling industry has been outrageous. Are redwoods, blue whales, tigers, and condors, to name but a few, to be only a matter of recorded legend for your great-grandchildren? While there is yet time, national and international organizations and governments must compel measures to assure that breeding populations of the great forms of terrestrial and marine wildlife survive, and that there be sufficient wilderness for solitary men to bathe in the grandeur of nature.

It is almost self-evident that population control, environmental quality, resource conservation, and the quality of life are all facets of a single central problem, which has become a central concern of governments. This may well be "the hinge of history" when man's long-term future may be decided. If we fail to manage these problems adequately, only the classical solutions of Tertullian may prevail, and it is doubtful whether civilization can survive. Hence, there is urgent need for an international organization adequate to these tasks which, in the end, cannot be left to the capricious judgments of so many individual national governments. Unfortunately, the history of the United Nations does not inspire confidence that it can successfully bring the nations of the world through the crisis of the rest of this century.

This international organization must, on rational scientific grounds, establish worldwide standards of acceptable quality for water, air, and foodstuffs and recommend international population policy. It must determine what level of extractive industry and manufacturing, worldwide, is compatible with those standards and population so that a

steady state may be achieved with nature, with the environment, and with use of both renewable and nonrenewable natural resources. Achievement of this goal will yet require a very substantial research and development effort. This does not gainsay the need for national efforts; quite the contrary, it is the latter which must be suggested, in part, and monitored by the international organization. The nature of this organization, its relation to the United Nations, its policing power, I leave to those more politically sophisticated than I. And there is little time to lose.

THE relatively recent internal history of the United States may help to illuminate diverse aspects of these problems. Until now, life in the United States was governed by the operation of the market economy; today all major decisions must be made in the public sector—but we have, as yet, little competence in this art.

Only this year has the Government organized for effective action in protecting the environment. But we still lack an adequate national policy with respect to conservation of resources and are timid in our approach to the population problem. We boast of our agricultural productivity but rarely give adequate credit to the remarkable continuing research and development effort—achieved by a combination of United States Department of Agriculture laboratories, State university agricultural schools, and industrial plant breeders; nurtured by a giant "agri-business"; and translated by a battalion of country farm agents—an enterprise that began when W. O. Atwater founded the first American experiment station in New Haven.

Science and technology underpin our economy, our se-

curity, our public health, and our food supply—but we lack a definitively formulated science policy, and our science effort is now threatened by lack of public support. Graduate and professional advanced education are very largely sustained by Federal funds—but neither Congress nor the Executive Branch has formally acknowledged Federal responsibility for these endeavors. We have had a Public Health Service for more than a century—but we have yet to establish the nature of Federal responsibility for the public health.

Only recently have we embarked upon a managed economy in the sense that Federal fiscal policy sets the environment for all economic decisions and gives rate and direction to the pace of the economy, while the Government budget itself, about one fifth of the Gross National Product, markedly influences the very nature of economic activity. In recent years, our Government has accepted the insurance function against such social hazards as unemployment, severe medical costs, or inadequate financial resources in old age. Soon the Government will serve as the employer of last resort, assuring some guaranteed minimal income for all. Perhaps uniquely among the nations of the world we have defined—in dollars per year—what we mean by the term "poverty," although the level so chosen would be regarded as affluence among many of the world's peoples. Abolition of poverty is a national goal that we can probably achieve whenever we deliberately so choose.

Importantly, there is insufficient recognition that the science-based technology responsible for the material well-being that has engendered these changes is thus responsible for the New Enlightenment itself. Our seemingly new-found concern for the welfare of our fellow man is

occasioned by the great wealth born of technology, which will not permit our consciences to ignore long-standing disparities. Moreover, the illiterate and uneducated, once an economic asset as a pool of unskilled labor, are no longer so needed, hence must be educated to more responsible, rewarding roles in our society, to again become assets rather than social burdens.

Although individual or corporate activity, on its own initiative, can contribute much to the solution of environmental, agricultural, or health problems, in this country only action at the Federal level can be effective if acceptable goals are to be achieved on a reasonable time scale.

Each of these situations finds analogy among other nations the world over as well as for the community of nations as a whole, albeit perhaps not yet on the same time scale. Accordingly, as we have already noted, the challenge is to fashion an imaginative, universally acceptable international instrumentality that can use the best of our scientific and technological capabilities in the worldwide interest of man. This agency must be as temperate and conservative as it is determined, must understand that the terms "pure air," "pure water," and "pure food" are essentially without meaning, as is the word "safe" when applied to drugs or food additives. Each requires quantitative definition with respect to specific individual components, and usually that will entail a trade-off analogous to that which determines the status of the steroid contraceptive pill.

Much the same considerations apply to a total ban on chlorinated hydrocarbon pesticides before more adequate substitutes are found, as they do to a recent proposal to ban construction of internal combustion engines after the year 1975. Granted the unpleasantness of air pollution, granted

the very small threat to life now posed by carbon monoxide, lead, sulfite, and nitrogen oxides in automobile emissions, but knowing that all can be markedly reduced if not eliminated, such legislation suggests that the trade-off for a more comfortable atmosphere is to forgo the freedom of transportation we have enjoyed.

I doubt that the American people would knowingly accept that trade, particularly if it were understood that a switch to electric-powered automobiles cannot now solve the problem. The energy for moving automobiles, trucks, and buses must come from somewhere; if we are to use battery power, then those batteries must be charged and recharged. And we are already in difficulty as to where and how to locate electricity-generating stations, which present their own unsolved environmental problems.

Proposals for "zero tolerance" for all food additives and for all drugs with respect to untoward consequences to the consumer are of the same character.

What are the trade-offs? Surely one asks only that the benefits to life of a life-saving drug considerably exceed the hazards of its administration. If it be a food additive that is a nutrient known to be toxic only in very large excess—as are vitamin A and vitamin D—but not known to be toxic in amounts commensurate with nutritional requirements, then I see no objection to fortification of food preparations, even though the amount added exceeds that present in the basic native unprocessed foodstuff. There is nothing sacrosanct in the composition of natural foods; their composition reflects not nature's design for human nutrition, but rather the chemical mixture appropriate to the functioning or propagation of the species of plants and animals which are our foods. If fortification with synthetic amino acids or

vitamins is the cheapest way to assure adequate nutritional levels, it is folly to stand in the way.

The immense benefit of fortification of wheat and corn with lysine should be made available wherever these cereals are the principal source of dietary protein. The nutritional benefits of combining foodstuffs relatively deficient in differing essential nutrients have been known since the turn of the century. They should be made available in the less developed countries. But this requires education, crop diversification, a market economy, and at least minimal technology. We may be grateful that several AID–USDA programs are designed to these ends.

If the additive itself be without intrinsic nutritional value, but somehow necessary to assure that the full nutritional properties of the foodstuff reach the consumer, and there is no substitute, rigorous standards are required to establish what level of risk is acceptable. Lethality is quite out of the question, but an incidence of one reversible untoward incident per 500,000 consumers, for example, may be an acceptable risk.

If, however, the additive offers no form of nutritional value but is present to enhance flavor or texture, the public is entitled to assurance that such addition is quite without hazard, viz., failure to detect metabolic or physiological alterations, abnormalities of development, mutations, or neoplasia. By failure is meant that the odds against such unwanted effects are at least greater than a million to one at ordinary levels of intake, with no detectable chance of lethality whatsoever. We sadly lack a data base for making such statements concerning most additives or many drugs; past studies of toxicity in its various forms have invariably used too few animals, too few species, and too brief obser-

vational times. Most such data antedate our appreciation of the possibilities for mutagenesis or carcinogenesis.

This is not to urge that food additives be removed immediately from all food preparations but, rather, that we embark upon the extremely large effort required to obtain such data. International cooperation in this endeavor would build useful bridges among nations while reducing the costs to all and shortening the time required to obtain the requisite information. Whether that should be another function of the proposed new international agency or an arm of an existing unit of the United Nations is of small moment. What matters is that we get on with the task. Until such time, let us behave rationally rather than "run scared" as we have done with respect to cyclamates and DDT.

THE current overly emotional worldwide awakening to the undesirable side effects of some facets of our technological civilization has led to diminution in public support of the scientific endeavor. Whether this derives from simple know-nothing anti-intellectualism, informed repugnance, or simple ignorance, the effect is the same—demands for a moratorium in the pace of the scientific endeavor, reduction in support for the education of tomorrow's scientists.

I could not disagree more violently. For all of our difficulties, the fact remains that the technology science makes possible is the principal tool this civilization has fashioned to alleviate the condition of man. If life is to be better tomorrow than it was yesterday, we shall require more and

better science-based technology rather than less. If we retreat from scientific research today, if we fail to educate a large, diversified corps of scientists, some capable of working at the disciplinary frontiers, others trained and motivated to function in multidisciplinary teams gathered to address one of the multitudinous societal problems, we shall also fail to construct a platform for the technology of tomorrow, and our great-grandchildren will not thank us.

The scientific and technical communities have failed to convey the nature of their endeavors, their successes, failures, and problems to the public at large. For most citizens, science is usually equated with "big science," the science of radio telescopes and large accelerators, the science that gives us colored television, the engineering that put a man on the moon.

But there is not equivalent public understanding of the "small science" that gives us an abundance of natural and synthetic fibers, the science that has made modern agriculture nothing short of miraculous, that accounts for the myriad nutritious and convenient products to be found in every supermarket. There are few more glorious tales in the annals of mankind, few activities by which so many have benefited, and yet there is minimal public appreciation of this endeavor.

What fraction of our public is aware of the decades of scientific breeding that provided the great variety of crop-plant strains now resistant to a host of environmental hazards, the careful studies of the nurture required for each such strain, the sophisticated utilization of genetic understanding, including the surprisingly successful, deliberate creation of polysomy by breeding techniques, which by virtually inventing new plant species have so enriched

the American table, the painstaking studies of animal nutrition and breeding that have made possible the world's most bountiful protein supply?

Every school child should learn that in agricultural research one must keep running simply to remain even as environmental hazards catch up with yesterday's breeding successes, that much remains to be done if aquiculture is to become a commercial reality on a meaningful scale, if unicellular organisms are to become important foodstuffs, in short, if we are to assure an adequate future food supply for the entire world.

All must understand that, although the world population will double by the year 2000, simple doubling of agricultural productivity will not suffice. We can no longer tolerate the widespread protein and vitamin A deficiencies in tropical countries that so limit their development. Nothing less than a quadrupling of the productivity of the biosphere in the next 30 years will suffice if mankind's basic needs are to be met. The magnitude of that task for agricultural producers and food processors is self evident; that it may be feasible is suggested by the record of the "Green Revolution." But time will not wait. We must get on with these tasks immediately if the full human potential of mankind is to be realized. If population control fails, all mankind will one day be destined at best to eat vegetable equivalents of milk, chicken, or beef.

In general, the public is somewhat better informed with respect to the nature and rewards of medical research than it is with respect to agricultural research. Yet here, too, misunderstanding and incomprehension are the norm. Publicity is given to what are termed "breakthroughs" when these are but the visible tips of the research iceberg.

The public, Congressmen, and even some medical practitioners demand that medical schools devote themselves to the production of "ordinary practicing doctors" in great numbers, at the expense of research activity, meanwhile demanding that such activity be more directly addressed to important problems of disease rather than exploring the nature of life, demanding that limited Federal resources be diverted from support of research to the delivery of health services. They could not be more wrong.

As Ivan Bennett noted, what is really meant by "medical care" is the mobilization of resources of manpower and facilities to bring to bear inadequate half-way technologies. When research provides a basis for truly definitive prevention or therapy, invariably the resultant control of a disease is enormously simpler and cheaper than the palliative half-way technologies that were used before.

Moreover, each time this sort of advance has occurred, it has been the consequence of fundamental insight into underlying disease mechanisms provided by basic research. Consider, if you will, a partial list of such diseases, each of which was at one time a major drain on the then extant health care system but is now of little consequence in this sense: infectious diseases such as tuberculosis, typhoid fever, infantile diarrhea, epidemic meningitis, typhus, trachoma, scarlet fever, poliomyelitis, cholera, yellow fever, bacterial endocarditis, syphilis, gonorrhea, lobar pneumonia, measles, rubella, whooping cough, diphtheria, smallpox, tetanus, or puerperal sepsis—nutritional diseases such as pellagra, kwashiorkor, rickets, scurvy, iron deficiency anemia, and pernicious anemia, or Addison's disease, hyperthyroidism, goiter, juvenile diabetes, glaucoma, erythroblastosis fetalis, and Parkinsonism. In every case,

today, their control or prevention is relatively simple and cheap. It is not these diseases, now under control, that pose the great problems of logistics, manpower, and costs for the current health-care system.

In contrast stand those only partly understood diseases that can be mitigated only by major efforts—but for which we lack definitive cures or preventive measures. It is these which now demand the most complex technologies research has yet made available to the modern hospital—technologies, nevertheless, which constitute only palliative or physiologically corrective measures. These disorders engender large human and financial cost and frustrate the health-care system, not because of shortage of professional manpower or of hospital facilities, but primarily because there is so little truly effective medical technology available even in the very best of circumstances. This is true for most forms of cancer, stroke, coronary thrombosis, myocardial infarction, hepatic cirrhosis, glomerulonephritis, pyelonephritis, rheumatoid arthritis, osteoarthritis, acute rheumatic fever, disseminated lupus, bronchial asthma, multiple sclerosis, the senile psychoses, schizophrenia, mental retardation, emphysema, most genetic disorders of metabolism, muscular dystrophy, cystic fibrosis, and virtually all the virus disorders that are not preventable by early immunization.

There are promising avenues of research with respect to practically all of these disorders. None is regarded as a hopeless problem by those engaged in its study; an atmosphere of confidence is shared by the research community in almost each instance, in large measure the consequence of the rapidly developing understanding of normal structure, physiology, and metabolism in molecular terms,

permitting rational, penetrating questions concerning the etiology and pathogenesis of disease. Elimination of the major lethal and incapacitating diseases that now afflict mankind is not a hopeless dream but a rational projection into the future, based on the capabilities of the present.

Whereas, if this Nation forswears research progress, it must plan for at least 50 percent more hospitals, more doctors, more nurses, more sanitaria, and more suffering by the turn of the century—scarcely a brave sight.

Biological research has laid the foundations for modern agriculture and can continue to do so; the way has been fashioned for alleviation, if not elimination, of the major killers of mankind. Biological research can thus provide the means whereby our planet can sustain a large mass of humanity, the quality of whose lives will vary inversely with their numbers.

Is *Homo sapiens,* then, as we know him, the end of biological evolution? Is man, the first product of evolution capable of controlling his own evolution, to put an end to that evolution? Are we another evolutionary blind alley? Perhaps.

By outwitting the forces of nature, man's numbers have burgeoned. By controlling his environment he has circumvented the driving force of natural selection which guided evolution in the past. By finding euphenic solutions to genetic disease—low phenylalanine diets for phenylketonurics, milk-free diets for galactosemics, insulin for diabetics, acetazolamide for periodic paralysis, allopurinol for gout, etc.—we have even contributed to the deterioration of our own genetic stock, minimizing the deleterious effects of genes that formerly were extinguished in homozygotes. If that is all we do with our understanding, then evolution

will not only have halted but retrogressed. Yet this need not be so.

Fairly soon, we must surely take the minimal step of aborting homozygotic fetuses bearing serious genetic disease detectable by routine, safe procedures. One day we may learn to use the technique of viral transduction, successful in bacteria, to introduce the genes for the enzymes missing from the tissues of individuals so afflicted. But that is but one more form of euphenic therapy and would again contribute to deterioration of the genetic stock. This is the sense in which the term "genetic engineering" has been employed, and I find little attraction in the prospect.

Experimentation with the genetic possibilities of mankind seems repugnant today, but undoubtedly the time will come when man's curiosity will stir him to explore the full potential of his own genes. Whether this takes the form of deliberate breeding by selection of biological mates or selective use of artificial insemination, by making replicate copies of admirable individuals, or even deliberate creation of mutants remains to be seen. But experimental manipulation of the human germ plasm in a deliberate attempt to create a strain of humans selected for some attribute must be reserved to a remote future when man is far more certain of himself and his values. In the interim, the random mating we have always known is but a relatively small sampling of the immense variety inherent in the human gene pool and creates a sufficiently intriguing human diversity.

Science *is* capable of fulfillment of our dream. Biological and physical research can permit us to refashion ourselves and our world. If the dream fails, it will be because of the limitations of man the social creature, evidence for which

is to be found daily on the front pages of our newspapers. Despite the frenetic concern for environmental pollution, there is really no question whether man can live with his technology. The real question is whether man can learn to live with himself.

Just as ecology is too immature to cope with our vast environmental problems, the social sciences are too young to cope with our most pressing national and international problems—terminating the war in Southeast Asia, establishing a stable permanent peace, learning to deal with political terrorism and the challenge to the legitimacy of government, achieving a successful progressive modus vivendi in our racial problems, coping with violence and crime, reconstruction and management of large cities, curbing the drug culture, developing an adequate system for the delivery of health care, abolishing poverty, illiteracy, and ignorance the world over, in addition to the various problems we have already discussed.

It is not at all obvious that we have the understanding or the social and political institutions to deal with these furious challenges—but seek them we must. Meanwhile, the long upward struggle of man from his animal origins affords cause for hope.

In view of the contributions of science to society, yesterday, today, and surely tomorrow, we scientists are shocked to find science under attack—yet this is nothing new.

Many are permanently humiliated by lack of understanding of science and its tools, or hold science accountable for real or imagined abuses of power, finding us guilty of destruction of the environment and even of generating the population problem by preserving life. Yet, surely, no other course is open to us but to use our growing

understanding in the service of man.

Petronius, an official of Nero's court, said, "It is not the shrines of the gods nor the powers of the air that send the dreams which mock the mind with flitting shadows; man makes his own dreams." Science is still the instrument with which he can make those dreams come true.

Dr. Philip Handler, the 1970 W.O.Atwater Memorial Lecturer, is President of the National Academy of Sciences, the Nation's most important scientific body.

Through the years, Dr. Handler has established a nationwide reputation as an articulate and persuasive spokesman for science, and as one familiar with the political mechanisms through which science can work for the good of society.

Dr. Handler has long had an interest in nutrition. His early work as a research biochemist at Duke University was devoted to studying some of the problems of basic biochemistry related to nutritional disorders. In 1950, at the age of 32, he was named chairman of the Biochemistry Department and later, James B. Duke Professor of Biochemistry.

Increasingly, Dr. Handler became involved with the politics of science—a decision motivated by his growing concern over the role that science should play in meeting people's needs. He accepted numerous advisory positions in several national agencies, including the National Institutes of Health, National Science Board of the National Science Foundation, and the Veterans Administration.

He served for three years as a member of the President's Science Advisory Committee and, since 1966, has served as chairman of a historic survey of modern biology. This survey culminated in a definitive book, "Biology and the Future of Man," which details current knowledge in the biological sciences and indicates future trends. Dr. Handler edited the book.

Dr. Handler was elected President of the National Academy of Sciences in 1969.

Previous Lecturers

1968	Dr. Artturi I. Virtanen Director, Biochemical Research Institute Helsinki, Finland Addressed the Federation of American Societies for Experimental Biology Atlantic City, N.J., April 16
1969	Dr. Albert Szent-Gyorgyi Director, Institute for Muscle Research Marine Biological Laboratory, Woods Hole, Mass. Addressed the American Chemical Society New York, N.Y., September 10

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